News

- I had a talk at an UEH meeting last Thursday:
  - https://indico.cern.ch/event/1015224/contributions/4268930/attachments/2206734/3733815/MCPs_followUpOnTheEbRequestTalk_v02.pdf
  - Exotics conveners sent out a request to form the EB on March 8th, no news since then;

- Two hot topics probably to be discussed with EB soon enough:
  - uncertainty on the late-muon-trigger efficiency;
  - uncertainties have a weird effect on the limits (?).

Weird behavior of the limits

- It’s strange how the uncertainties affect the limits: even a very large change of the uncertainties leads to an insignificant change of the limits, often in a direction opposite to the expected one;

- Jackson B.: observed something similar, was due to the “better-than-zero” issue;
  - may it explain what we see?

“Better-than-zero” issue

- It came up several times already that when people observed no signal and set the 95% CL limits on its production cross-section, they actually reported to have < 3 events in the numerator of $\sigma_{limit} = \frac{N}{\mathcal{L}\cdot\varepsilon}$;
- The “better-than-zero” note: https://cds.cern.ch/record/2280679 ;
- It claims that anything smaller than 3 events will be incorrect, as solving $\beta = \sum_{n=0}^{n_{obs}} \frac{b^n e^{-b}}{n!}$ for b given $\beta = 0.05$ (95% CL) yields $b = 2.996 \approx 3$ already in case of $n_{obs} = 0$;
- However, when we encountered the same issue in the course of our 36.1 fb^{-1} @ 13 TeV analysis and asked the stats forum for help, they actually agreed that in some cases reporting less than 3 events is correct;
- Their statement exists as a separate document: https://groups.cern.ch/group/hn-atlas-physics-Statistics/Lists/Archive/Attachments/3502/betterThanZeroAddendum.pdf ;
- The full discussion of the issue: https://groups.cern.ch/group/hn-atlas-physics-Statistics/Lists/Archive/Flat.aspx?RootFolder=%2Fgroup%2Fhn-atlas-physics-Statistics%2FLists%2FArchive%2FAn%20addendum%20for%20better%20than%20zero&FolderCTID=0x012002005BEAF7AF2FD5874E9BFF6477F931DD94 ;
- Unfortunately, the “better-than-zero” note was never updated with this important discussion, and it still claims that < 3 events is incorrect, which is rather misleading.

“Better-than-zero” issue

- That separate statement features the following table:

Signal yield uncertainty	95% CL_s upper limit
0	2.996
0.05	2.894
0.1	2.824
0.2	2.757
0.25	2.759
0.3	2.786

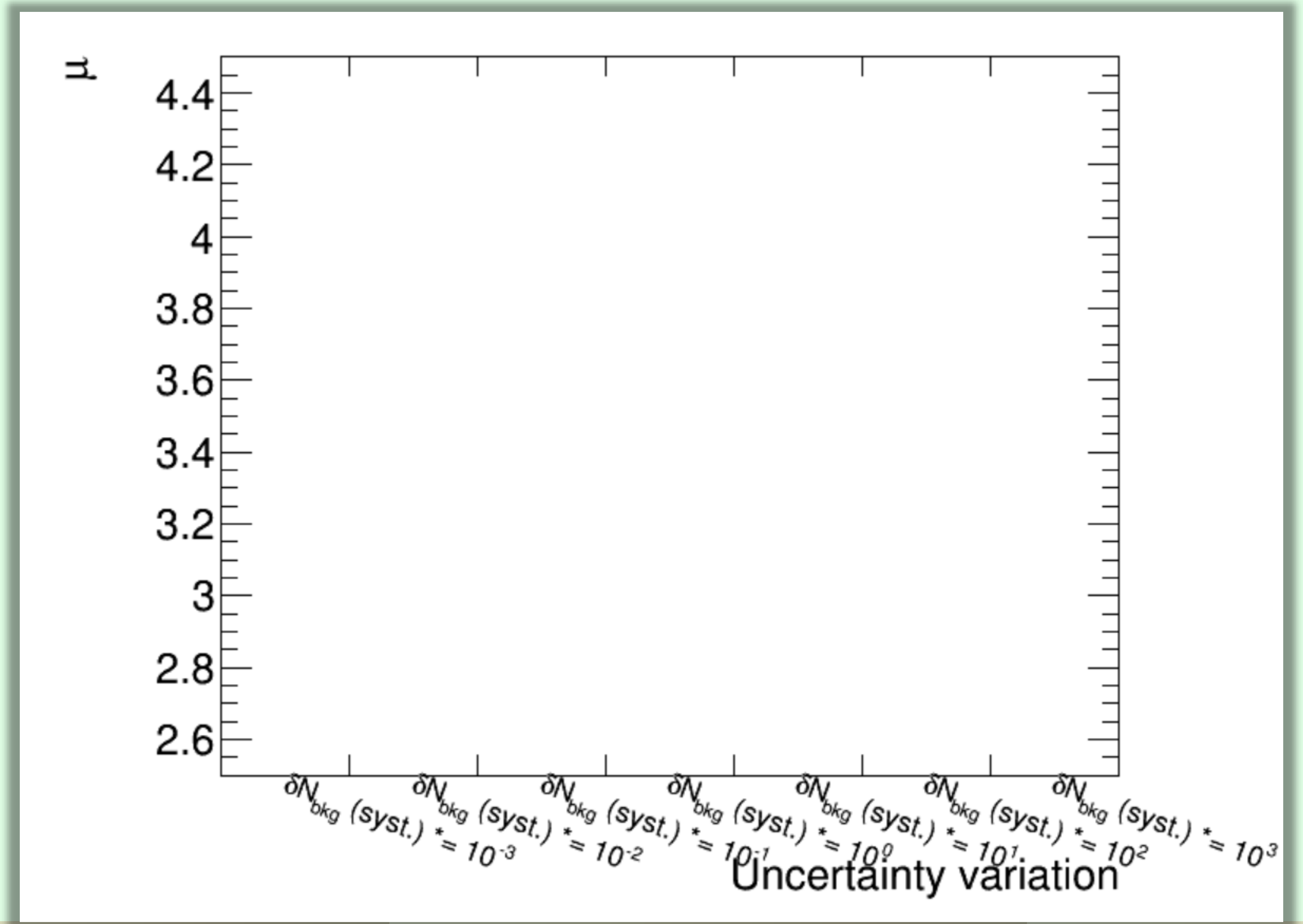
- The uncertainty increases but the limits get more stringent at first (which is counterintuitive) up to some point, then they get less stringent as expected;

- Isn’t it what we observed?

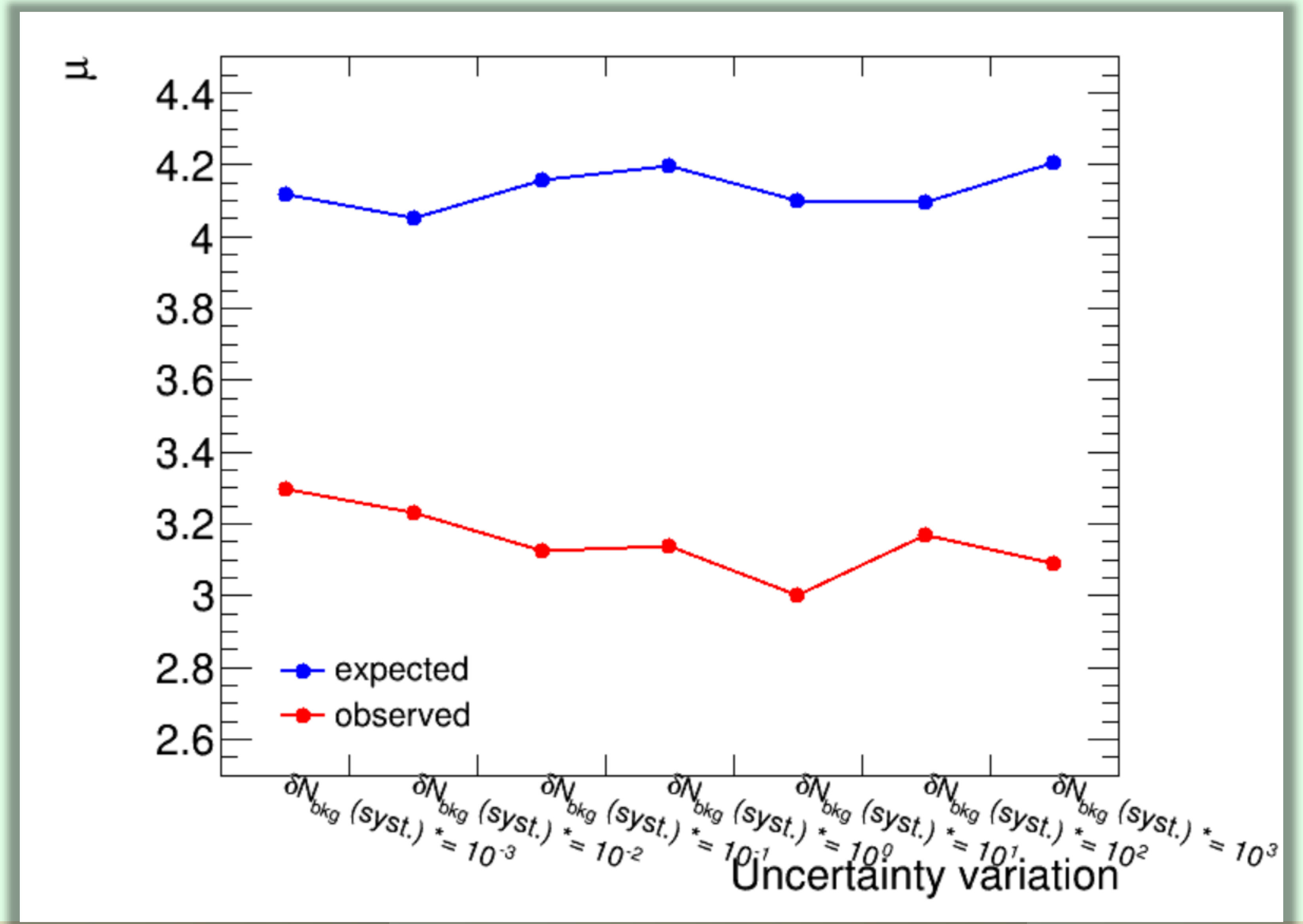
Which samples to check?

Mass [GeV] \ z	2	3	4	5	6	7
500	✓					
800						
1100						
1400			✓			
1700						
2000						✓

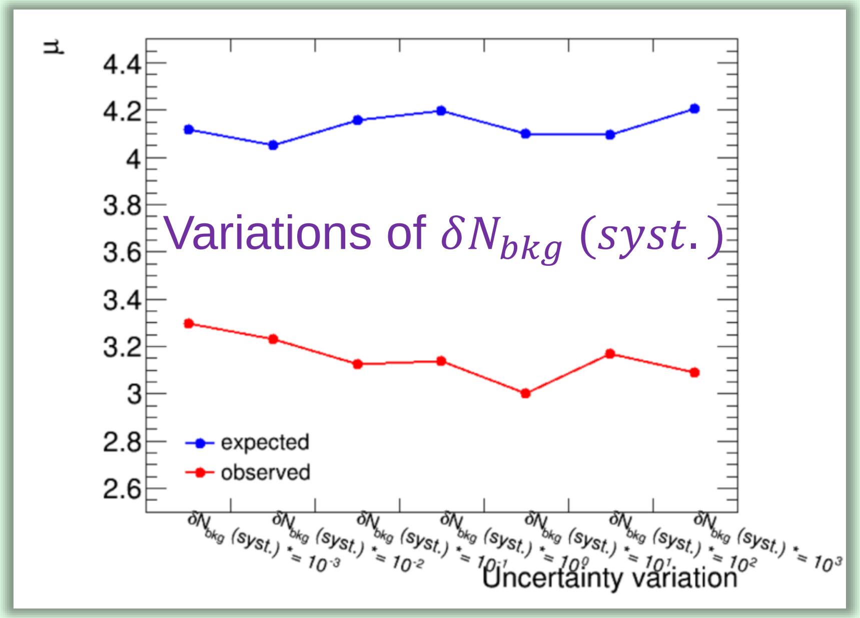
Variations of the systematic uncertainty on the bkg expectation for m=500 GeV, z=2 MCP sample

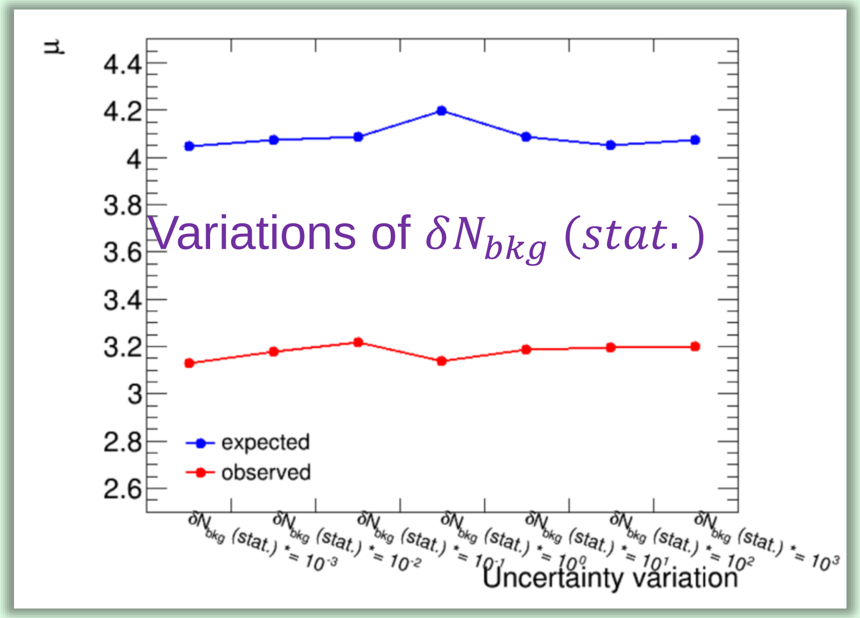


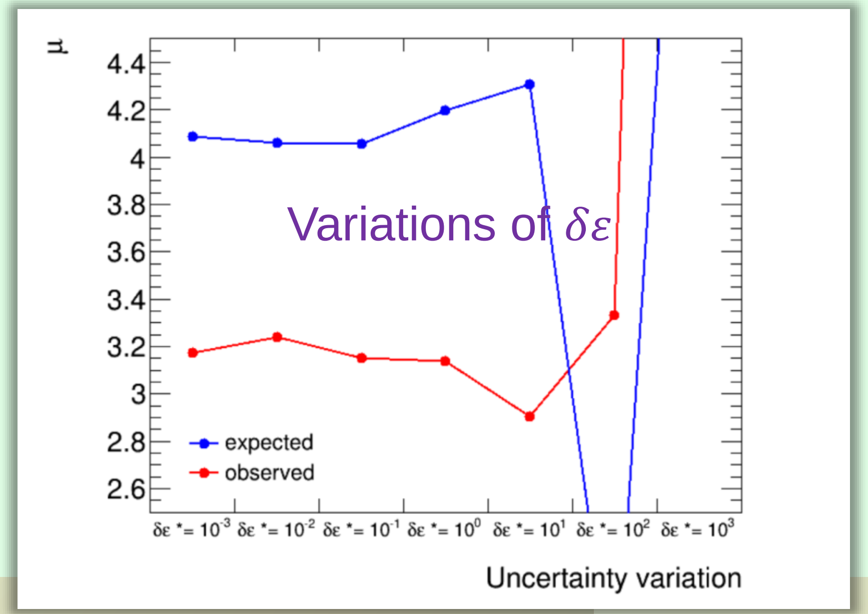
Variations of the systematic uncertainty on the bkg expectation for m=500 GeV, z=2 MCP sample

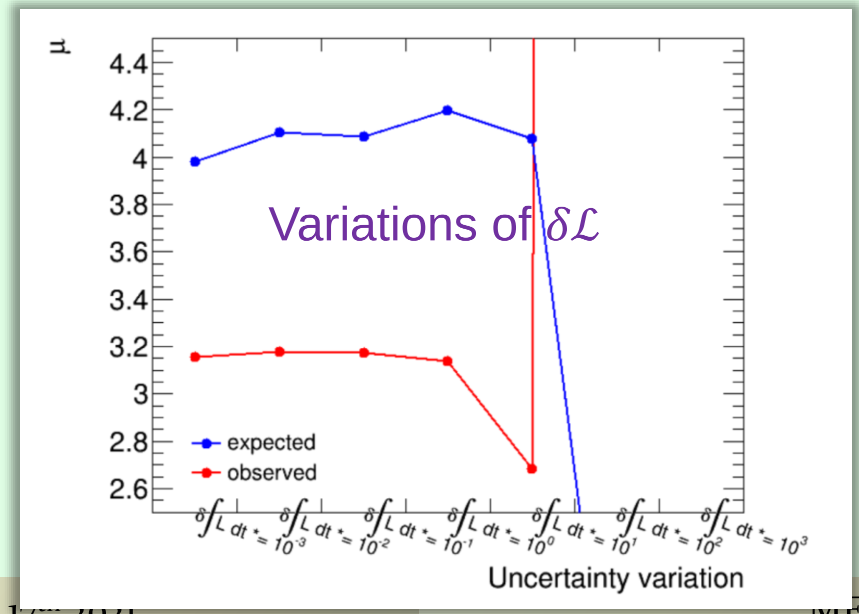


Variations of every uncertainty for m=500 GeV, z=2 MCP sample



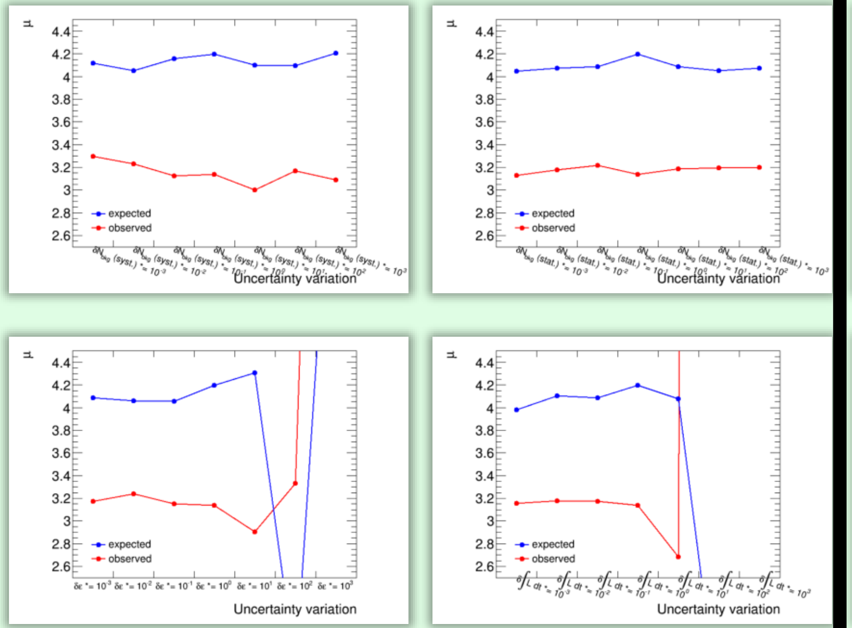




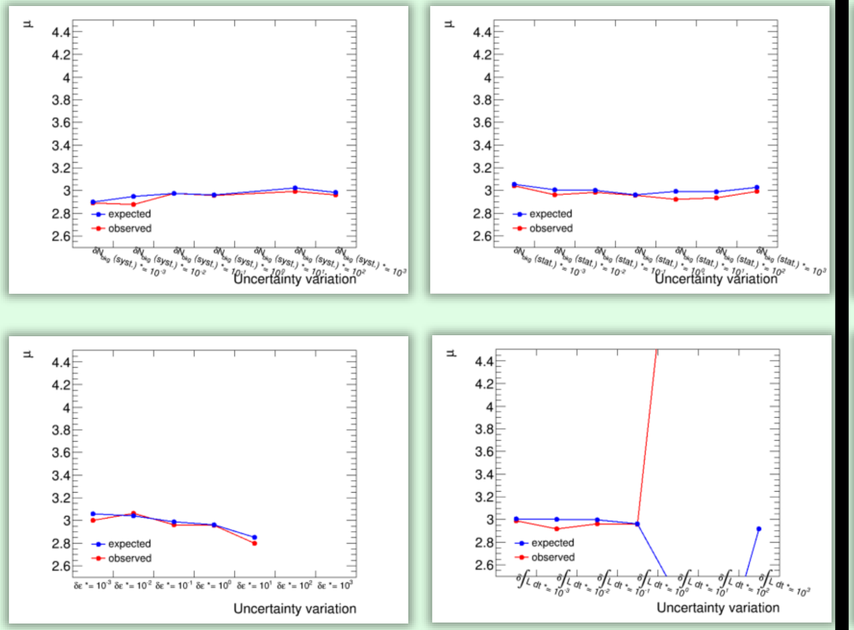


Variations of every uncertainty for each of three samples

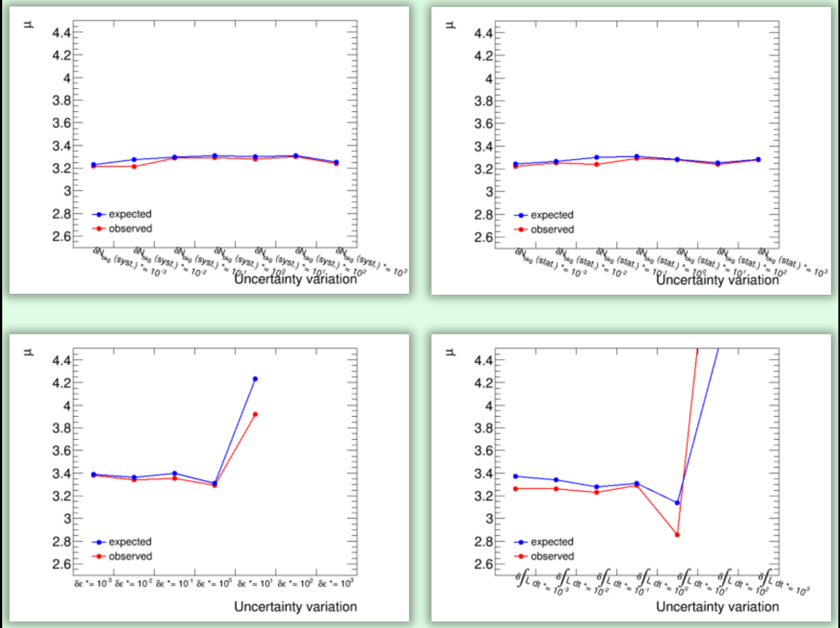
m=500 GeV, z=2



m=1400 GeV, z=4



m=2000 GeV, z=7



It does not look to me like it is related to the better-than-zero problem in any way

Explanation other people had

- I asked Jackson and UEH conveners about these plots;

- My surprise knew no bounds when they said this is more or less the behavior they expected;

- Cristiano A.: “The behaviour you see is due to a relatively known effect associated to the discreteness of the Poisson distribution. When you are running with no systematic you “suffer” from having a discrete distribution, therefore, small changes (±1 event) can make a big difference. When you add a systematic (i.e. by multiplying the pdf by a Gaussian), you basically remove the discreteness, and you get better expected limits.”.

Explanation other people had

Hi Yury,

I don't think there is anything wrong with your limits. The behaviour you see is due to a relatively known effect associated to the discreteness of the Poisson distribution.
When you are running with no systematic you "suffer" from having a discrete distribution, therefore, small changes (+-1 events) can make a big difference. When you add a systematic (i.e. by multiplying the pdf by a Gaussian), you basically remove the discreteness, and you get better expected limits.

I have run a simple S+B model considering 2 bkg events, 0 observed with 5k toys. When I set the systematic very small (0.0002) I get this result

```
expected limit (median) 3.01797
expected limit (-1 sig) 2.98913
expected limit (+1 sig) 3.08795
expected limit (-2 sig) 2.92015
expected limit (+2 sig) 3.17261
observed 3.03962
```

while when I set it to 2% (0.02) for both signal and bkg, I get

```
expected limit (median) 2.99779
expected limit (-1 sig) 2.95425
expected limit (+1 sig) 3.0355
expected limit (-2 sig) 2.84442
expected limit (+2 sig) 3.08868
observed 3.01161
```

while if I set it to 20% (0.20) I get this

```
expected limit (median) 2.75535
expected limit (-1 sig) 2.46059
expected limit (+1 sig) 3.11064
expected limit (-2 sig) 1.96958
expected limit (+2 sig) 3.45641
observed 2.76229
```

As you can see, the expected and observed limits get better when I add even a tiny systematics, since I'm "removing" the discreteness.

Cheers,
Cristiano

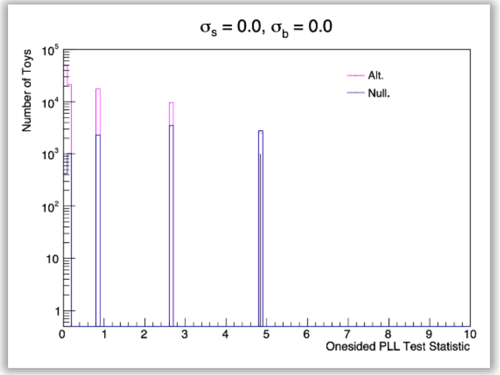
Explanation other people had

- Jackson agrees:

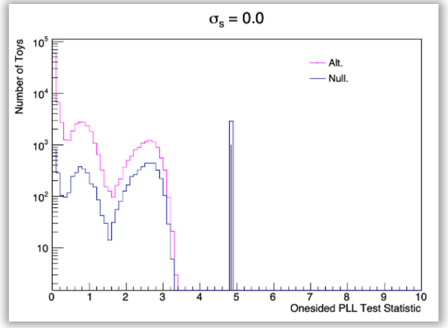
Hi Yuri,

I agree with Cristiano, these plots are more or less what I would expect to happen in the case of zero background. I can try to provide a bit more explanation of the phenomenon based on studies that I performed for VH(4b).

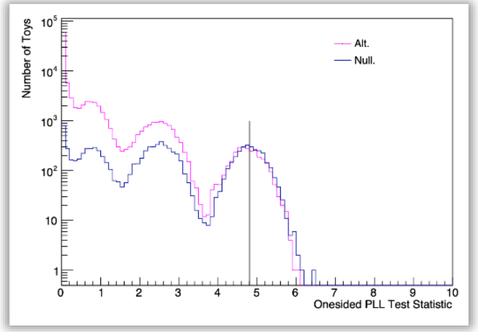
As Cristiano alluded to, when all systematics are turned off, the distribution of the test statistic will be a series of delta functions. The plot below shows these distribution for the null and alt. hypotheses, and the observed value of the test stat as a black line centered in the final peak.



What I found surprising was that even when introducing a systematic uncertainty on the background (i.e. σb != 0), the final peak is still a delta function when you do not include any systematic uncertainty on the signal.



As soon as you introduce an uncertainty on the signal (no matter how small), this delta function will be smoothed out for both hypotheses, but if you work through the math you can show that the distribution for the alt hypothesis will be slightly shifted to the left w.r.t the null, as shown below. This is the source of the tighter limits observed with increasing systematics (p_b stays the same, p_s decreases).



Happy to discuss this further, I just typed up a more detailed description of this for my thesis that I would be happy to share with you.

Final thoughts on this

- Before receiving these emails from Jackson and Cristiano yesterday, I have also shown my setup to a person who exploits the same approach to calculate the limits, hoping she could find an obvious mistake in it – no reply yet.

On the uncertainty on the late-muon-trigger efficiency

Searches for heavy long-lived charged particles with the ATLAS detector in pp collisions at $\sqrt{s} = 8$ TeV

Draft version v14.06.18

Not reviewed, for internal circulation only

ATLAS NOTE

June 18, 2014

Searches for heavy long-lived charged particles with the ATLAS detector in *pp* collisions at $\sqrt{s} = 8$ TeV

Abstract

Searches for long-lived charged particles are performed using a data sample of 19.1 fb^{-1} from proton-proton collisions at $\sqrt{s} = 8$ TeV collected by the ATLAS detector at the LHC. Stable staus in GMSB models with $N_5 = 3$, $M_{\text{messenger}} = 250$ TeV and sign(μ) = 1 are excluded at 95% confidence level up to a mass of 432, 430, 416, 402, 376 GeV for $\tan\beta = 10$, 20, 30, 40 and 50 respectively. Directly produced stable sleptons are excluded at 95% confidence level up to mass of 373–330 GeV for $\tan\beta = 10 - 50$.

Squarks and gluinos masses have been excluded at 95% confidence level up to mass, respectively of 1000 GeV and 1150 GeV in simplified LeptoSUSY models where sleptons are stable and degenerate with a mass of 300 GeV and all neutralinos (except $\tilde{\chi}_1^0$) and charginos are decoupled.

Long lived charginos, nearly degenerate to the lightest neutralino in simplified SUSY models, are excluded at 95% confidence level up to mass of 619 GeV .

For *R*-hadrons we observe a lower mass limit at 95% confidence level of 1270 GeV for gluinos, 781 GeV for sbottoms and 886 GeV for stops. A selection relying solely on the inner detector and calorimeters, thereby covering e.g. *R*-hadrons hadronising into neutral bound states before reaching the muon spectrometer, yields a lower mass limit of 1262 GeV for gluinos, 758 GeV for sbottoms and 868 GeV for stops.

https://cds.cern.ch/record/1638776

The triggers they used

- they used traditional in-time single-muon trigger and the MET trigger;

- impossible to estimate the single-muon-trigger efficiency for particles with $\beta < 1$ (or $\beta \ll 1$) based on data → estimated from signal MC but special care is taken for the RPC simulation:
  - two corrections for RPC;
  - no correction for TGC, just like in our case;
  - I feel we already do the same in a way, but we introduce the SFs and say this is our final single-muon-trigger efficiency, and they take the systematic uncertainty as a difference between the nominal single-muon-trigger efficiency and the one after applying the SFs;
  - not sure yet I fully understand their procedure, I'll have to talk to Shlomit some more about it;
  - their resulting uncertainty on the single-muon-trigger efficiency is 2.9%-3.4%.

THANKS!

Table 9.3 Poisson lower and upper limits for n_{obs} observed events.

n_{obs}	lower limit a			upper limit b		
	$\alpha = 0.1$	$\alpha = 0.05$	$\alpha = 0.01$	$\beta = 0.1$	$\beta = 0.05$	$\beta = 0.01$
0	–	–	–	2.30	3.00	4.61
1	0.105	0.051	0.010	3.89	4.74	6.64
2	0.532	0.355	0.149	5.32	6.30	8.41
3	1.10	0.818	0.436	6.68	7.75	10.04
4	1.74	1.37	0.823	7.99	9.15	11.60
5	2.43	1.97	1.28	9.27	10.51	13.11
6	3.15	2.61	1.79	10.53	11.84	14.57
7	3.89	3.29	2.33	11.77	13.15	16.00
8	4.66	3.98	2.91	12.99	14.43	17.40
9	5.43	4.70	3.51	14.21	15.71	18.78
10	6.22	5.43	4.13	15.41	16.96	20.14

This is the result of solving $\beta = \sum_{n=0}^{n_{obs}} \frac{b^n e^{-b}}{n!}$ for b

For the upper limit at a confidence level of $1 - \beta = 95\%$ one has $b = -\log(0.05) = 2.996 \approx 3$. Thus if the number of occurrences of some rare event is treated as a Poisson variable with mean ν, and one looks for events of this type and finds none, then the 95% upper limit on the mean is 3. That is, if the mean were in fact $\nu = 3$, then the probability to observe zero would be 5%.